COLLEGE OF ENGINEERING, PUNE

Term 2013-14

Department of Mechanical Engineering

T. Y. Mechanical

End Semester Examination

ME 9005 HEAT TRANSFER

Time 3.00 hr] **[Max. Marks: 60**

Instructions:

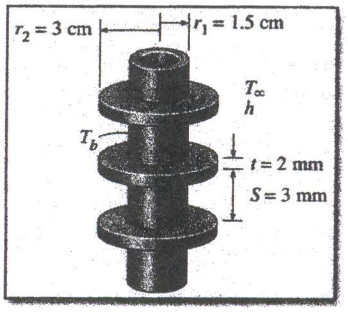
1. **All questions are compulsory.**
2. Make suitable assumptions and use suitable standard data wherever necessary.
3. Illustrate your answers with neat sketches wherever required.
4. Use of steam table, Heat Transfer data book and non-programmable calculator is permitted.
5. Figures to right indicate full-marks.
6. **Enough importance will be given to the neatness of writing and stepwise calculations.**

Q1 a. Derive the one-dimensional transient heat conduction equation for a plane wall with constant thermal conductivity and heat generation in its simplest form, and indicate what each variable represents. Further prove that $\frac{d^2T}{dx^2} = 0$ **5**

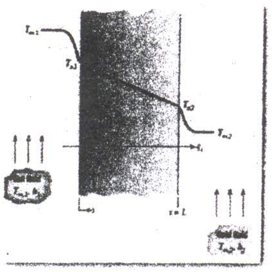
b. Consider a large plane wall of thickness L=0.2 m, thermal conductivity k=1.2 W/m · °C, and surface area A=15 m^2. The left side of the wall and right side of wall are maintained at constant temperatures of T1=120°C and T2=50°C, respectively. Using the differential equation of heat conduction determine: (a) the variation of temperature within the wall and the value of temperature at x=0.13 m and (b) the rate of heat conduction through the wall under steady conditions. **5**

OR

b Steam in a heating system flows through tubes whose outer diameter is D_1=3 cm and whose walls are maintained at a temperature of 120°C. Circular aluminium fins (k =180 W/m·°C) of outer diameter D_2=6 cm and constant thickness t =2 mm are attached to the tube, as shown in Fig. The space between the fins is 3 mm, and thus there are 200 fins per meter length of the tube. Heat is transferred to the surrounding air at T_∞=25°C, with a combined heat transfer coefficient of h=60 W/m^2·°C. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins. **5**



Q2 a. Consider the plane wall of Figure 3.1, separating hot and cold fluids at temperatures $T_{\infty,1}$ and $T_{\infty,2}$, respectively. Using the basic heat conduction equation and using surface energy balances as boundary conditions at x=0 and x=L(see Equation 2.34), obtain the temperature distribution within the wall and the heat flux in terms of $T_{\infty,1}$ $T_{\infty,2}$, h_1, h_2 , k, and L. **5**



b. In a materials evaluation program, dielectric-coated glass beads of 12.5 mm diameter are removed from a process oven with a uniform temperature of 225 °C. The beads are cooled in an air stream for which T_∞=20 °C and the convection coefficient is 25 W/m^{2}K. What is the temperature of a bead after 6 min? 5

Assume properties of gas as glass: ρ=2225 kg/m^3, C_p=835 J/kg.K, k=1.4 W/m.K.

OR

b A plane wall is a composite of two materials, A and B. The wall of material A has uniform energy generation of 1.5x10^5 W/m^3, k_A=75 W/m.K and thickness L_A=50 mm. The wall of material B has no generation, with k_B=150 W/m.K and thickness L_B=20 mm. The inner surface of material A is well insulated, while the outer surface of material B is cooled by a water stream, with T_∞=30°C and h=1000 W/m^2.K.

(a) Determine the temperature T_0 of the insulated surface and the temperature T_2 of the cooled surface.

(b) Sketch the temperature distribution that exists in the composite under steady-state conditions.

Q3 a. If a thin and long fin is insulated at its tip, show that the heat transfer from the fin is given by $Q_{fin} = \sqrt{hPkA_c}\,(T_o - T_\infty)\tanh mL$, where the terms carry their usual meaning. 5

b. An ordinary egg can be approximated as a 5-cm-diameter sphere. The egg is initially at a uniform temperature of 5°C and is dropped into boiling water at 95°C. Taking the convection heat transfer coefficient to be h=1200 W/m^2·°C, determine how long it will take for the centre of the egg to reach 70°C. The water content of eggs is about 74 percent, and thus the thermal conductivity and diffusivity of eggs can be approximated by those of water. 5

OR

b Consider a 5-m-high, 8-m-long, and 0.22-m-thick wall whose representative cross section is as given in the figure. The thermal conductivities of various materials used, in W/m · °C, are k_A=k_F=2, k_B=8, k_C=20, k_D=15, and k_E=35. The left and right surfaces of the wall are maintained at uniform temperatures of 300°C and 100°C, respectively. Assuming heat transfer through the wall to be one-dimensional, determine

(a) the rate of heat transfer through the wall;

(b) the temperature at the point where the sections B, D, and E meet; and

(c) the temperature drop across the section F. Disregard any contact resistances at the interfaces.

Q4 a Explain with neat sketch forced convection vaporization in a vertical tube. Also show diagrammatically the variation of heat transfer coefficient with quality. 5

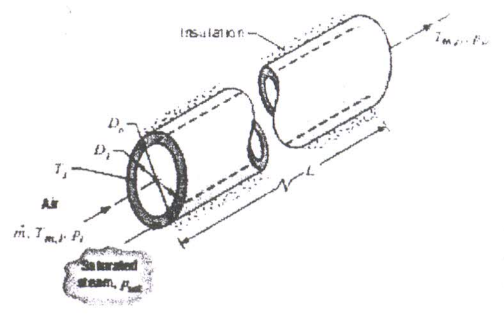
b Experiments have been conducted on a metallic cylinder 12.7 mm in diameter and 94 mm long. The cylinder is heated internally by an electrical heater and is subjected to a cross flow of air in a low-speed wind tunnel. Under a specific set of operating conditions for which the upstream air velocity and temperature were maintained at V=10 m/s and 26.2 °C, respectively, the heater power dissipation was measured to be P=46 W, while the average cylinder surface temperature was 5 determined to be T_s=128.4 °C. It is estimated that 15% of the power dissipation is lost through the cumulative effect of surface radiation and conduction through the end pieces.

i) Determine the convection heat transfer coefficient from the experimental observations.

ii) Compare the experimental result with the convection coefficient computed from an appropriate correlation.

OR

b An air heater for an industrial application consists of an insulated, concentric tube annulus, for which air flows through a thin-walled inner tube. Saturated steam flows through the outer annulus, and condensation of the steam maintains a uniform temperature Ts on the tube surface. 5



Consider conditions for which air enters a 50-mm-diameter tube at a pressure of 5 atm, a temperature of $T_{m,i}$=17 °C, and a flow rate of 0.03 m/s, while saturated steam at 2.455 bars condenses on the outer surface of the tube. If the length of the annulus is L=5 m, what are the outlet temperature $T_{m,o}$ and pressure p_o of the air? What is the mass rate at which condensate leaves the annulus?

Q5 a With reference to radiation heat transfer, explain with illustration

(i) Summation Rule 2

(ii) Superposition or additive rule 2

(iii) Rule of Symmetry 1

b Consider two large diffuse-gray (infinite) parallel planes (1 and 2) with temperatures and emissivity of T_1, ε_1 and T_2, ε_2. Show that the ratio of the radiation transfer rate with multiple shields, N, of emissivity ε_s to that with no shields, N=0, is 5

$$\frac{q_{12,N}}{q_{12,0}} = \frac{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1\right)}{\left(\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1\right)+N\left(\frac{2}{\varepsilon_S}-1\right)}$$

where $q_{12,N}$ and $q_{12,0}$ represent the radiation heat transfer rates for N shields and no shields, respectively.

Consider two large, diffuse, gray, parallel surfaces separated by a small distance. If the surface emissivity of both surfaces is 0.8, what emissivity should a thin radiation shield have to reduce the radiation heat transfer rate between the two surfaces by a factor of 10?

OR

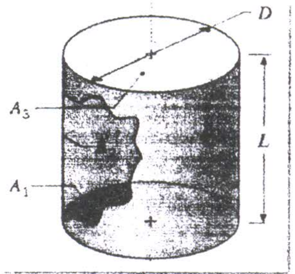
b Consider the right-circular cylinder of diameter D, length L, and the areas A_1, A_2, and A_3 representing the base, inner, and top surfaces, respectively.

(a) Show that the view factor between the base of the cylinder and the inner surface has the form

$F_{12}=2H[(1+H^2)^{1/2}-H]$, where $H=L/D$.

(b) Show that the view factor for the inner surface to itself has the form

$F_{22}=1+H-(1+H^2)^{1/2}$.



Q6 a Assume a parallel flow heat exchanger. Assuming the usual notations for hot and cold fluid, deduce an expression for LMTD. State all the assumptions. Write the expression of LMTD for a counter flow heat exchanger. What will be the $(\Delta T_m)_{CF}$ if ΔT_i and ΔT_o are same. **5**

b A counter flow, concentric tube heat exchanger used for engine cooling has been in service for an extended period of time. The heat transfer surface area of the exchanger is 5 m^2, and the design value of the overall convection coefficient is 38 W/m^2K. During a test run, engine oil flowing at 0.1 kg/s is cooled from 110 ^0C to 66 ^0C by water supplied at a temperature of 25 ^0C and a flow rate of 0.2 kg/s. Determine whether fouling has occurred during the service period. If so, calculate the fouling factor, $R''f(m^2K/W)$.

OR **5**

b The condenser of a large steam power plant is a heat exchanger in which steam is condensed to liquid water. Assume the condenser to be a shell-and-tube heat exchanger consisting of a single shell and 30,000 tubes, each executing two passes. The tubes are of thin wall construction with D=25 mm, and steam condenses on their outer surface with an associated convection coefficient of h_o=11,000 W/m^2K. The heat transfer rate that must be effected by the exchanger is $q=2\times10^9$ W, and this is accomplished by passing cooling water through the tubes at a rate of 3×10^4 kg/s (the flow rate per tube is therefore 1 kg/s). The water enters at 20°C, while the steam condenses at 50°C. What is the temperature of the cooling water emerging from the condenser? What is the required tube length L per pass?